PATENT COOPERATION TREATY

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P.7350.WOP	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/GB2004/001618	International filing date *(day/month/year)* 14.04.2004	Priority date *(day/month/year)* 14.04.2003
International Patent Classification (IPC) or national classification and IPC G01F1/00		
Applicant SENTEC LIMITED et al.		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 4 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:

   a. ☒ *sent to the applicant and to the International Bureau)* a total of 12 sheets, as follows:

   ☐ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).

   ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:

- ☒ Box No. I — Basis of the opinion
- ☐ Box No. II — Priority
- ☐ Box No. III — Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV — Lack of unity of invention
- ☒ Box No. V — Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI — Certain documents cited
- ☐ Box No. VII — Certain defects in the international application
- ☒ Box No. VIII — Certain observations on the international application

Date of submission of the demand 12.11.2004	Date of completion of this report 04.04.2005
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Politsch, E Telephone No. +49 89 2399-8455

Form PCT/IPEA/409 (Cover Sheet) (January 2004)

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages

1, 9-15	as originally filed
2-8, 8a, 8b	received on 11.02.2005 with letter of 11.02.2005

Claims, Numbers

1-17	received on 11.02.2005 with letter of 11.02.2005

Drawings, Sheets

1/7-7/7	as originally filed

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* If item 4 applies, some or all of these sheets may be marked "superseded."

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/GB2004/001618

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-17
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-17
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-17
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

1. REMARKS ON V. REASONED STATEMENT UNDER RULE 66.2(a)(ii) WITH REGARD TO NOVELTY, INVENTIVE STEP OR INDUSTRIAL APPLICABILITY

Articles 33(2), (3) PCT

The subject-matter of all claims fulfils the requirements of Articles 33(2) and (3) PCT as to novelty and inventive step.

None of the presently available prior art documents nor any combination thereof discloses or hints at an electrode comprising a metal with an electrochemically deposited or sintered salt layer or a partially reduced salt layer.

Hence, claims 1 and 3 (see also the objection concerning lack of conciseness below) and consequently all dependent claims fulfill the requirements of Articles 33(2), (3) PCT.

2. REMARKS ON VIII. CERTAIN OBSERVATIONS ON THE INTERNATIONAL APPLICATION

Lack of conciseness (Article 6 PCT)

Claims 1, 2 and 3, 4

Although claims 1, 2 and 3, 4, respectively, have been drafted as separate independent claims, they appear to relate effectively to the same subject-matter and to differ from each other only with regard to the definition of the subject-matter for which protection is sought. The difference between claims 1, 2 and 3, 4, respectively, is defined in terms of the result to be achieved. However, as becomes clear from the description, for instance, the lower noise characteristic of the electrode is achieved by the technical features, i.e. by the metal comprising an electrochemically deposited or sintered salt layer or the partially reduced salt layer.

Hence, the two different alternatives according to the present invention are effectively defined by claims 1 and 3. The aforementioned claims therefore lack conciseness and as such do not meet the requirements of Article 6 PCT.

reduces such interface problems. Such a flow transducer is a magnetic flow transducer of a kind that is well known: GB1303730A discloses a transducer in which the electrodes comprise elongated copper-containing conductor wire surrounded by a pervious insulation materal. SU800650B discloses a flow meter in which an electrode is enveloped by the use of a protective system in the form ~~of~~ a galvanic pair consisting of a grid electrode made of catalytic material for reinstatement of oxygen and directly coupled to an anode which surrounds the measuring electrode and made of stationary potential material with respect to reinstatement of oxygen. US3299703 claims a flow meter in which electrodes are placed in recesses formed in the internal wall of a flow conduit and where a wetting agent is placed in the recesses between the electrodes and the liquid. JP54116960A discloses a flow meter in which a pair of electrodes are supplied with a positive potential so as to keep the electrode surfaces clean.

Such a flow transducer is also shown by way of example in the cross-sectional view of figure 1. Flow tube, 101 incorporates a magnetic transducer 109 comprising a pair of electrodes, 102, disposed across a diameter of the pipe 101, with at least part of one surface of each electrode 102 in intimate contact with the fluid 108 in the pipe. Magnetic pole pieces, 103, are disposed across the orthogonal diameter of the pipe 101 and linked by a magnetic circuit, 104. As is well known in the art, the magnetic field 107 imparts a force on charged species

moving with a bulk medium (ions in the case of water), causing the charged species to migrate in a direction orthogonal to both the magnetic field and the direction of bulk fluid motion. The mutual displacement of oppositely charged species results in an electric field along the direction of migration, which builds up until the electrostatic force on a given ion is balanced by the magnetic force. Since the magnetic force depends implicitly on the bulk medium flow velocity, measurement of the opposing electric field (or potential difference) provides a convenient means for determining the flow rate, whilst integration over time allows the total volume that has passed through the tube to be calculated. Circuitry for processing the electrode signals to obtain such measurements is well known in the art and consequently not described in greater detail here.

As is also well known, it can be advantageous to alternate the applied magnetic field, so as to overcome various limitations of a static field measurement. One such limitation is imposed by the nature of the electrodes used to measure the electrical potential difference in the fluid. An ideal electrode will form a perfect electrical connection to the fluid, with no energy barrier to the exchange of charge either way across the solid-liquid interface. This is seldom observed in practical systems, and it is much more likely that an electrical potential difference will be present across the interface. The potential difference is often poorly defined, and varies

randomly with time such that it exhibits a noise spectrum that is inversely proportional to frequency ('1/f). A static field (DC) measurement will therefore be subject to large instantaneous errors.

Alternating the applied magnetic field at a known frequency f_o partially overcomes this problem: as shown in figure 2, this results in the desired electrical signal 201 also being present at the frequency f_o which is chosen to be significantly higher than the characteristic frequency of the electrode noise spectrum 202. Measurement of the electrical signal amplitude a provides an indication of the flow rate that is substantially free of errors.

A further reason for applying an alternating magnetic field is that the small-signal electrical impedance of typical electrodes, as perceived by a measuring circuit attached between them, also falls with increasing frequency. The measuring circuit may therefore be permitted to draw more current from the signal source, without causing substantial errors. The principal advantage is that a simpler, cheaper measuring circuit design may be adopted.

To understand the frequency-dependent behaviour of the electrodes, it is useful to consider a simple electrical model of figure 3 that is often applied to the solid-liquid interface 301, consisting of a resistor 302 in parallel with a capacitor 303. The direct exchange of charged species between the solid 304 and the liquid 305 is signified by the flow of current through the resistor 302,

while the capacitor 303 represents the tendency of charged species to accumulate in the vicinity of the interface, without actually crossing it. At frequencies substantially above 1Hz, the capacitor 303 generally provides the easier route for the flow of a small-signal current through a solid-liquid interface.

In the device of figure 1, an alternating magnetic field is achieved by means of coils 105 wound around part of magnetic circuit 104 and supplied with a suitable alternating current waveform. Furthermore, to reduce power consumption, it is known to provide magnetic circuit 104 with one or more elements 106 exhibiting magnetic remenance so that the coils need only be energised when it is required to change the state of the magnetic field.

The present invention has as an objective yet further reduction in the power consumption of magnetic flow transducers.

DISCLOSURE OF INVENTION

Accordingly, the invention consists in a magnetic flow transducer having electrodes and an alternating magnetic field, wherein an electrode has lower noise energy at frequencies below 5Hz than an electrode comprising carbon or corrosion-resistant metal alloy and comprises a metal and a layer of a salt of that metal arranged such that it is interposed between the metal and the fluid, the layer being electrochemically deposited or sintered..

The invention is based on the recognition that by

using an electrode having lower noise energy at low frequencies than the electrodes conventionally used in water meters, the frequency of the alternating magnetic field can be reduced for the same signal to noise ratio which in turn reduces the power consumption of the transducer.

In contrast, the electrodes of known magnetic flow transducers are chosen for their immunity to corrosion effects and consequently made of corrosion-resistant metal alloys such as stainless steel or Hastelloy. In such known transducers, the electrochemical potential across the interface is poorly-defined, permitting large variations over a longer period of time, of the order of seconds. However, since known transducers operate at a magnetic field frequency much greater than 1 Hz, this has not caused problems. Thus, expressed differently, the invention also consists in a magnetic flow transducer having electrodes and an alternating magnetic field, wherein an electrode has a noise characteristic at magnetic field frequencies around 1 Hz that is lower than that of an electrode comprising corrosion-resistant metal alloy and comprising a metal and a layer of a salt of that metal arranged such that it is interposed between the metal and the fluid, the layer being electrochemically deposited or sintered.

The electrode according to the invention is configured such that a galvanic current flows across its interface with the fluid of the flow. A galvanic current

arises due to the movement or exchange of charged species through the solid-liquid interface. It is distinct from the displacement current which flows between the liquid and sensor electrodes in known magnetic flow meters and which flows as the result of opposing sheets of charge building up or dispersing either side of an interface without actually crossing the phase boundary. The galvanic current configuration significantly improves the electrical impedance and noise characteristics of the electrode.

Furthermore, the electrode according to the invention is configured such that the galvanic current is carried by ions. Silver ions are particularly advantageous since solid silver is stable in water over a long period of time and does not corrode significantly. Moreover, it is non-toxic and a permitted food additive (E174). Silver is also close to copper in the electrochemical series, reducing the risk of unwanted electrolytic corrosion in water pipes. It is also biocidal, helping to prevent stagnation and formation of troublesome biofilms in and around electrodes.

In addition, the arrangement of a metal and a salt of that metal interposed between the metal and the fluid of the flow assists the charge exchange between the conductor and the fluid that underlie galvanic current. The salt or ionic compound is preferably sparingly soluble in the fluid of the flow of which is to be measured and is thus retained at the electrode. Where the metal is silver,

the ionic compound may be a silver halide salt. Furthermore, where the fluid is water, such silver halide salts are advantageously formed by the ions most commonly present in tap water (chloride, fluoride). Silver halides form a stable electrochemical half-cells in contact with the metal.

In accordance with the invention, the layer of metal salt is electrochemically deposited on a metal surface, e.g by anodizing or comprises a sintered layer of metal salt on a metal surface. The thickness of the layer will affect the impedance of the electrode: if it is too thick, it will add an excessive series impedance to the total electric circuit, whereas if it is too thin, the concentration will be insufficient to maintain the required electrochemical reactions. The thickness of the layer is therefore preferably chosen, e.g. empirically, to lie between these two extremes such that the impedance of the electrode is at a minimum.

Further improvement in the noise and electrical characteristics may be achieved by an electrode having a metal surface that has been roughened so as to increase its active area. This may conveniently be achieved by reducing some of the metal salt back to metal, which typically results in a re-growth of metal that is non-uniform and rough. Accordingly, a second aspect of the invention consists in a magnetic transducer for measuring the flow of a fluid, the transducer having electrodes and an alternating magnetic field, wherein an electrode has

lower noise energy at frequencies below 5Hz than an electrode comprising carbon or corrosion-resistant metal alloy and comprises a metal and a layer of a salt of that metal arranged such that it is interposed between the metal and the fluid, the layer being partially reduced back to metal. Expressed differently, the second aspect of the invention consists in a magnetic transducer for measuring the flow of a fluid, the transducer having electrodes and an alternating magnetic field, wherein an electrode has a noise characteristic at magnetic field frequencies around 1 Hz that is lower than that of an electrode comprising carbon or corrosion-resistant metal alloy and comprises a metal and a layer of a salt of that metal arranged such that it is interposed between the metal and the fluid, the layer being partially reduced back to metal.

Preferably, a pair of electrodes of the magnetic flow transducer will be balanced so as to minimise the offset potential between the two. Each electrode acts as a separate electrochemical half-cell, with a corresponding potential difference relative to the liquid. If the electrodes are not identical, the difference between the two half-cell potentials will be present between the electrode terminals, and this may cause problems with the subsequent amplification circuitry (e.g. saturation).

The low-power advantages of the above invention are further enhanced by the reduction in power consumption obtained when the magnetic field is generated by means

exhibiting magnetic remenance as discussed above. The invention also comprises a flow meter incorporating such a magnetic transducer, where the low power consumption of the transducer also makes feasible the use of battery power (shown at 110 in figure 1) and the advantages in terms of ease of installation that this brings.

BRIEF DESCRIPTION OF DRAWINGS

The invention is diagrammatically illustrated, by way of example, in the accompanying drawings, in which:

Figure 1 is a cross-sectional view of a flow tube equipped with a magnetic flow transducer;

Figure 2 illustrates the amplitude/frequency characteristics of the signal from the electrodes;

Figure 3 is a simple electrical model of the solid-liquid interface;

Figure 4 shows an electrode of a first embodiment of

CLAIMS

1. Magnetic transducer (109) for measuring the flow of a fluid, the transducer having electrodes (102) and an alternating magnetic field (107), wherein an electrode has lower noise energy at frequencies below 5Hz than an electrode comprising carbon or corrosion-resistant metal alloy and comprises a metal (401) and a layer (402) of a salt of that metal arranged such that it is interposed between the metal and the fluid (403), the layer being electrochemically deposited or sintered.

2. Magnetic transducer (109) for measuring the flow of a fluid, the transducer having electrodes (102) and an alternating magnetic field (107), wherein an electrode has a noise characteristic at magnetic field frequencies around 1 Hz that is lower than that of an electrode comprising carbon or corrosion-resistant metal alloy and comprising a metal (401) and a layer (402) of a salt of that metal arranged such that it is interposed between the metal and the fluid, the layer being electrochemically deposited or sintered.

3. Magnetic transducer (109) for measuring the flow of a fluid, the transducer having electrodes (102) and an alternating magnetic field (107), wherein an electrode has lower noise energy at frequencies below 5Hz than an electrode comprising carbon or corrosion-resistant metal alloy and comprises a metal (401) and a layer (402) of a salt of that metal arranged such that it is interposed between the metal and the fluid, the layer being partially

reduced back to metal.

4. Magnetic transducer (109) for measuring the flow of a fluid, the transducer having electrodes (102) and an alternating magnetic field (107), wherein an electrode has a noise characteristic at magnetic field frequencies around 1 Hz that is lower than that of an electrode comprising carbon or corrosion-resistant metal alloy and comprises a metal (401) and a layer (402) of a salt of that metal arranged such that it is interposed between the metal and the fluid, the layer being partially reduced back to metal.

5. Magnetic transducer according to any preceding claim, wherein the layer (402)of salt is sparingly soluble in said fluid (403) the flow of which is to be measured.

6. Magnetic transducer according to claim 5, wherein the metal (401) is silver.

7. Magnetic transducer according to claim 6, wherein the layer (402) of salt comprises silver halide salt.

8. Magnetic transducer according to claim 7, wherein said silver halide salt is silver chloride or silver fluoride.

9. Magnetic transducer according to any one of claims 3 to 8, wherein said layer (402) is electrochemically deposited.

10. Magnetic transducer according to any one of claims 3 to 8, wherein said layer (402) is sintered.

11. Magnetic transducer according to any preceding claim, wherein the thickness of the layer (402) is such that the

impedance of the electrode is at a minimum.

12. Magnetic transducer according to any one of claims 1,2 and 5 to 11 when dependent thereon, wherein the surface of the electrode is roughened so as to increase its active area.

13. Magnetic transducer according to claim 12, wherein the layer (402) is partially reduced back to metal.

14. Magnetic transducer according to any preceding claim, wherein a pair of electrodes (102) of the magnetic transducer are balanced so as to minimise the offset potential between the two.

15. Magnetic transducer according to any preceding claim and comprising means (103,104,105) for generating the alternating magnetic field (107), said means exhibiting magnetic remenance.

16. Flow meter incorporating a magnetic transducer according to any preceding claim.

17. Flow meter according to claim 16, wherein the meter is battery (110) powered.